

ElectroSpark Deposition

Hard Chrome Alternatives Team
Joint Cadmium Alternatives Team
Canadian Hard Chrome Alternatives Team
Joint Group on Pollution Prevention
Propulsion Environmental Working Group

Replacement of Hard Chrome Plating
Replacement of Cadmium Plating
Program Review Meeting

23-25 January 2007

Marriott New Orleans at the Convention Center
859 Convention Center Blvd
New Orleans, LA 70130

Report Documentation Page				Form Approved OMB No. 0704-0188	
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Introductions

Norma Price

Advanced Surfaces And Processes, Inc.

ElectroSpark Deposition (ESD)
Results of Materials Testing and Technology Insertion

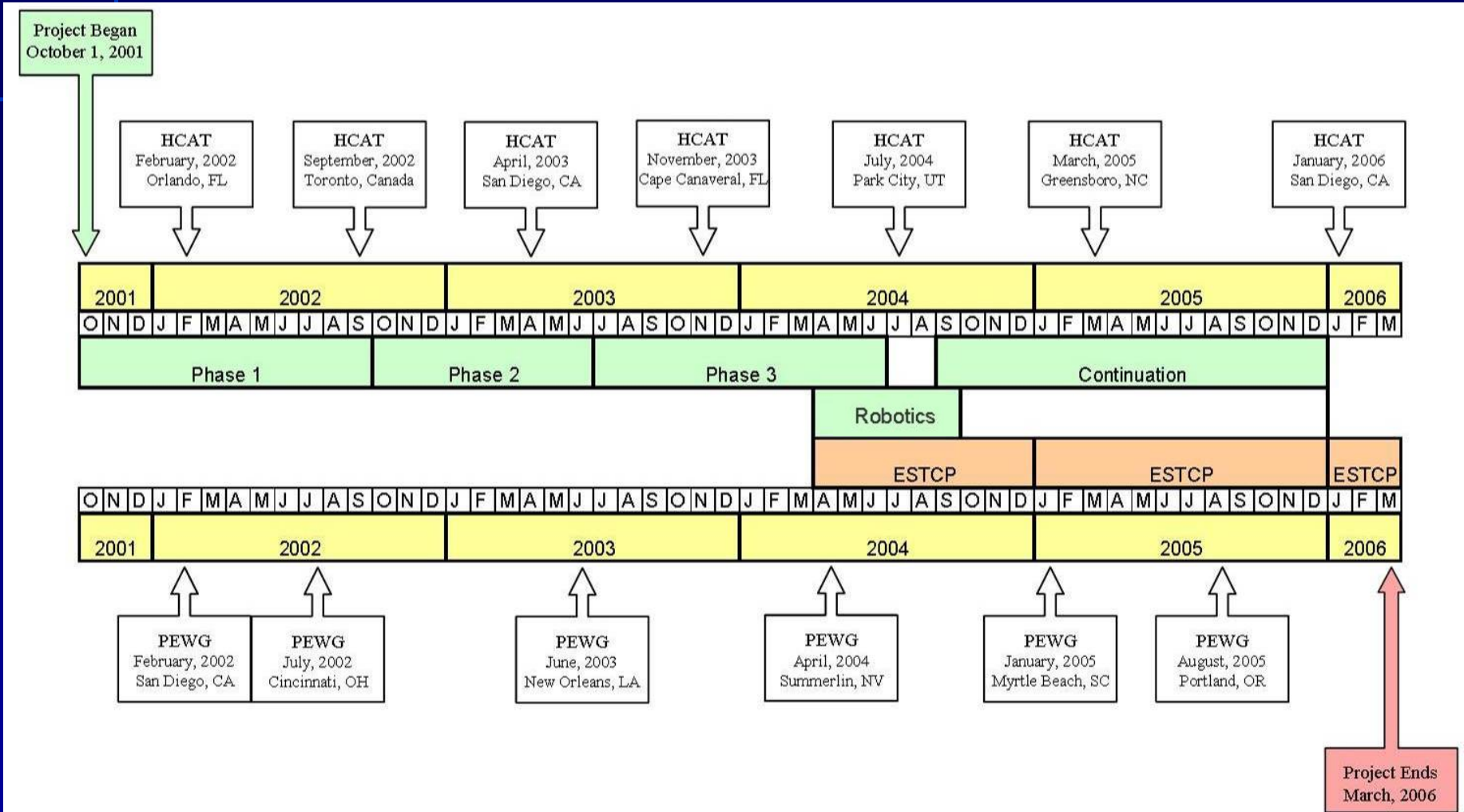
What is ESD?

The ESD process is comprised of generating an arc through a consumable electrode via capacitive discharge. The electrode and substrate materials are melted, rapidly solidify, and build-up occurs incrementally.

- Metallurgical bond
- Low heat input
- Rapid solidification
- No pre-ESD preparation
- No post-ESD processing
- Environmentally benign
- Portable
- Applicable for NLOS



History



Project Objective

The goals of this project were to *demonstrate and validate* ElectroSpark Deposition (ESD) as technically feasible and commercially viable for a production-scale process, and to perform the tests necessary to transition ESD for use on gas turbine engine components.



Participants

- ESTCP/HCAT
- PEWG
- Portland State University
- Edison Welding Institute
- General Electric Aircraft Engines
- Pacific Northwest National Lab
- Air Force Research Lab
- Metcut
- Hamilton Sundstrand
- Pratt & Whitney
- Tinker AFB
- Rowan Technology Group

Milestones

- ! Optimization of ESD (Material Studies)
- ! Joint Test Protocol (IN 718)
- ! Joint Test Protocol (three more materials)
 - 410 Stainless Steel
 - Ti-6Al-4V
 - Chrome-plated IN 718
- ! ESD/Robotics/UIT
- ! Components

Milestones

www.HCAT.org

HCAT Member WorkSpace

→ Projects and Partners

→ Hard Chrome Alternative Team

→ ESD - Electrosark Deposition for Repair (mostly GTEs) –
PEWG-HCAT Project EPP 0202 – COMPLETED Reports

→ Final Report

→ *ESD Final Report Draft.doc* (updated 8/17/2006)



Joint Test Protocol For Three Other Materials

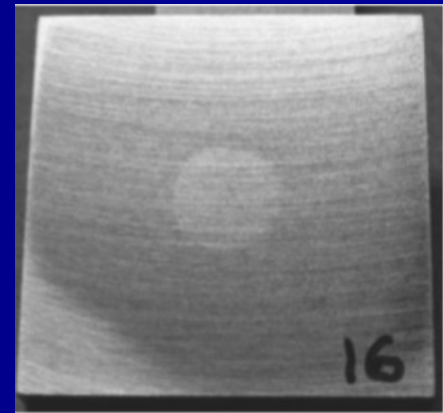
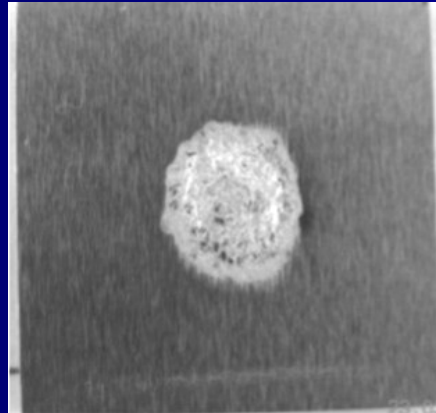
- 410 Stainless Steel
- Ti-6Al-4V
- Chrome-plated IN 718

Joint Test Protocol For Three Other Materials

- *Optimization*
 - *Deposition Rate*
 - *Microhardness*
 - *Discontinuities*
- *Fatigue*
- *Tensile*
- *Corrosion*

410 Stainless Steel

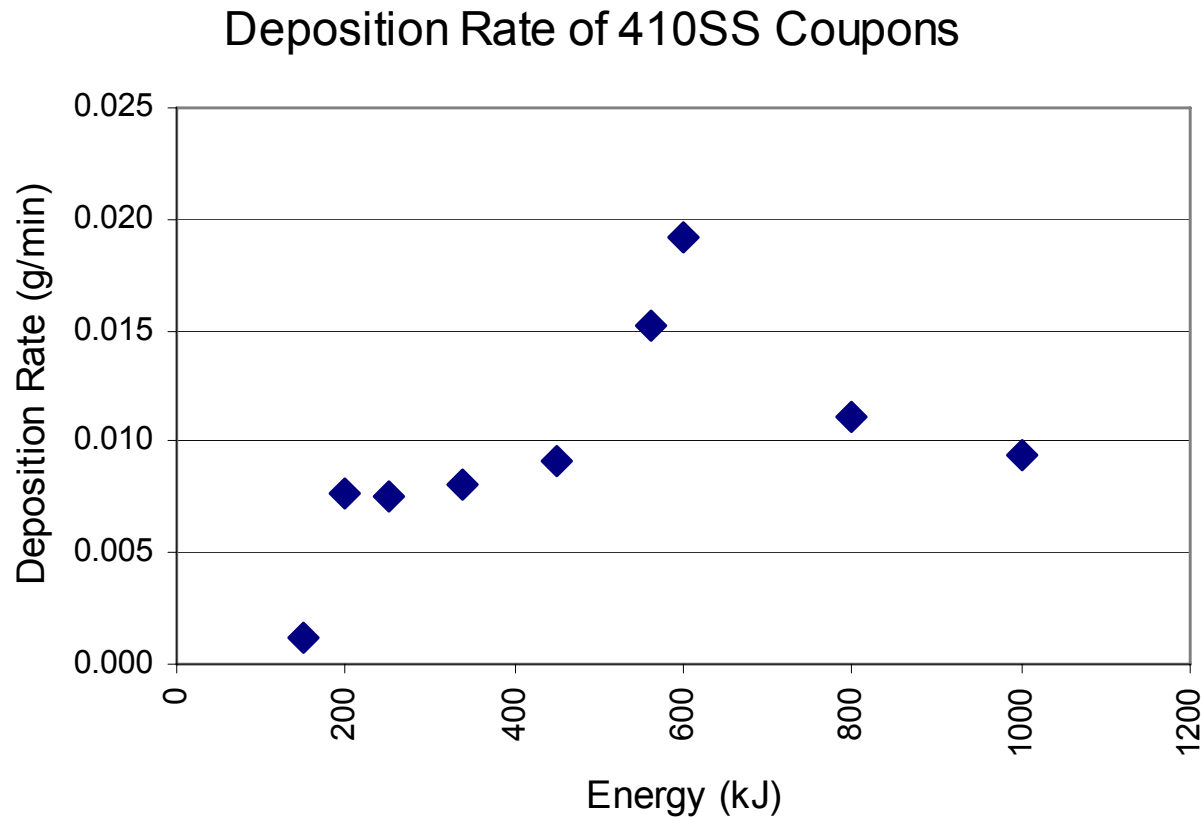
410 Stainless Steel Optimization



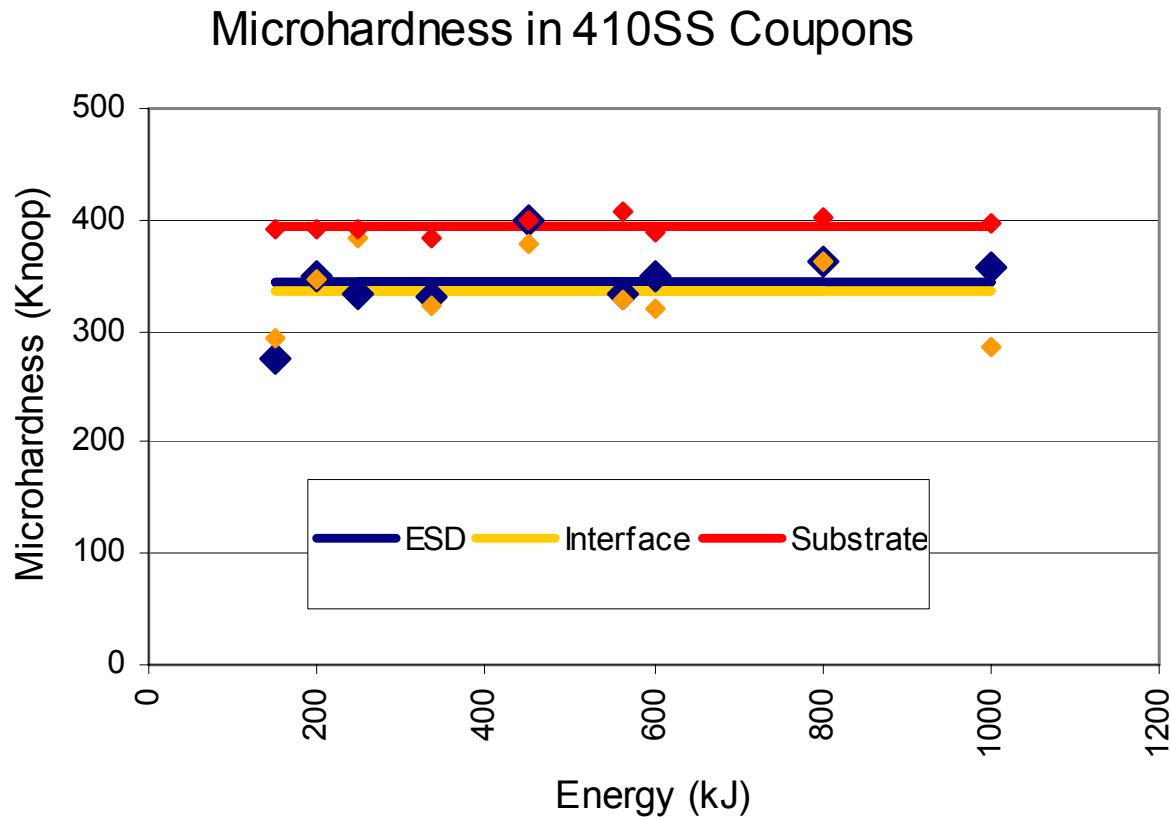
410 Stainless Steel Optimization

Run Order	Coupon Number	Pulse Rate (Hz)	Voltage (V)	Capacitance (mF)	Electrode Speed (rpm)
1	410-34	300	100	30	800
2	410-35	300	150	40	1200
3	410-36	300	200	50	1400
4	410-37	500	150	30	1400
5	410-38	500	200	40	800
6	410-39	500	100	50	1200
7	410-31	700	200	30	1200
8	410-32	700	100	40	1400
9	410-33	700	150	50	800

410 Stainless Steel Optimization

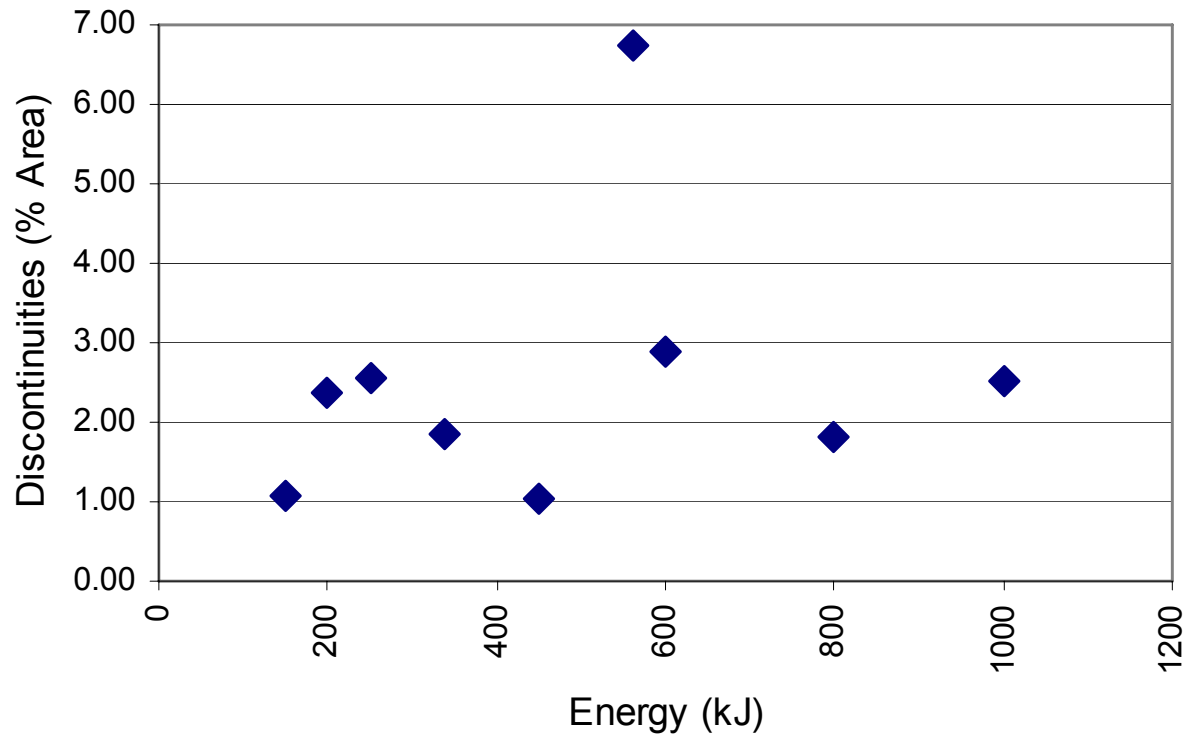


410 Stainless Steel Optimization



410 Stainless Steel Optimization

Discontinuities in 410SS Coupons



410 Stainless Steel

Parameters Selected

ESD Parameters – Based on DOE results:

- 500 Hz Pulse Rate
- 40 mF Capacitance
- 150 volts Voltage
- 1100 rpm electrode rotation speed

410 Stainless Steel

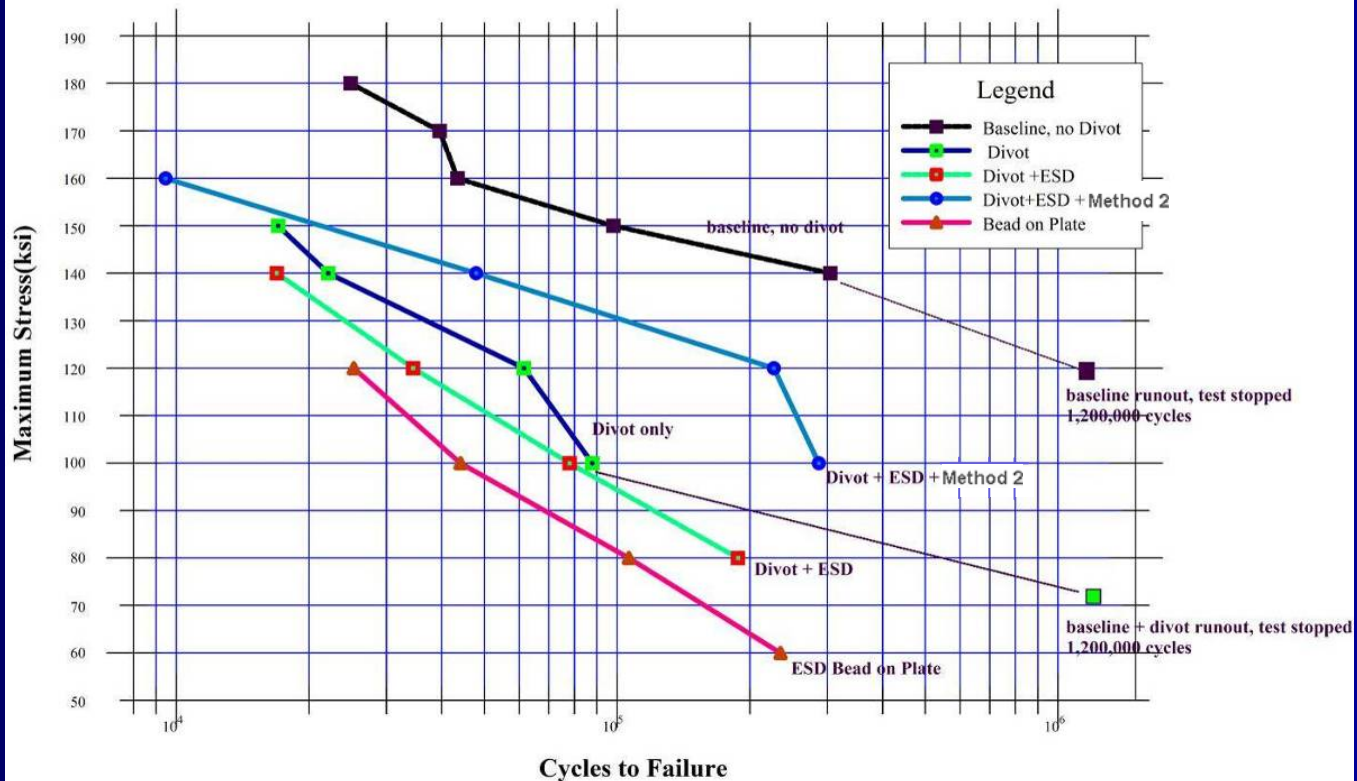
Fatigue

ASTM E466



410 Stainless Steel Fatigue

410 SS Axial Fatigue Test Results (R=0.05)



410 Stainless Steel

Tensile

ASTM E8



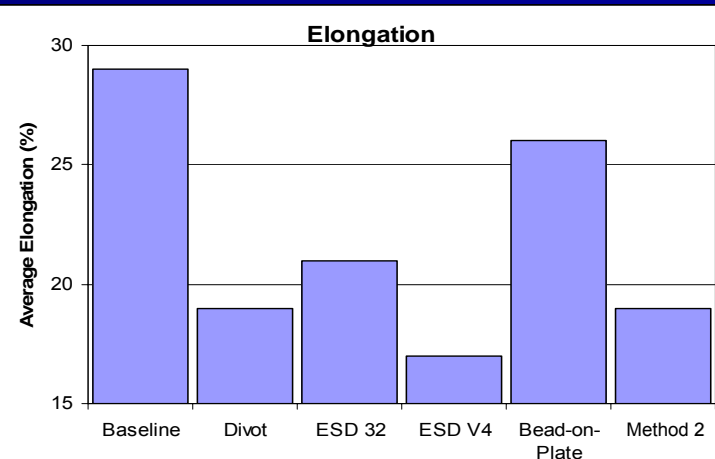
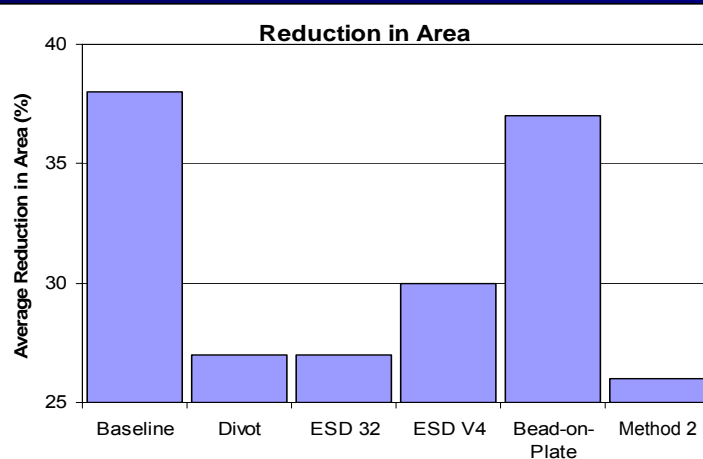
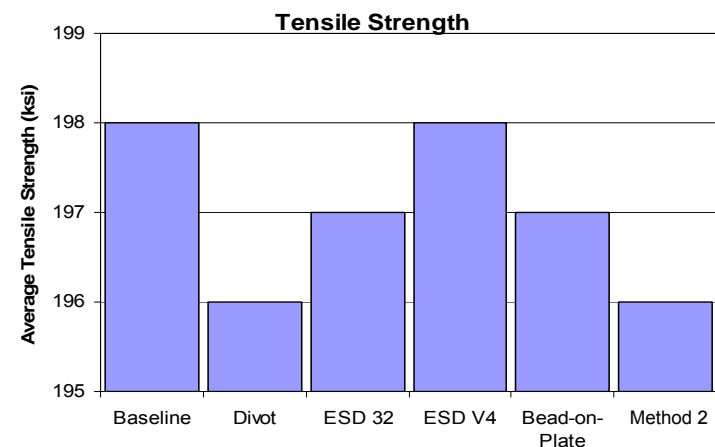
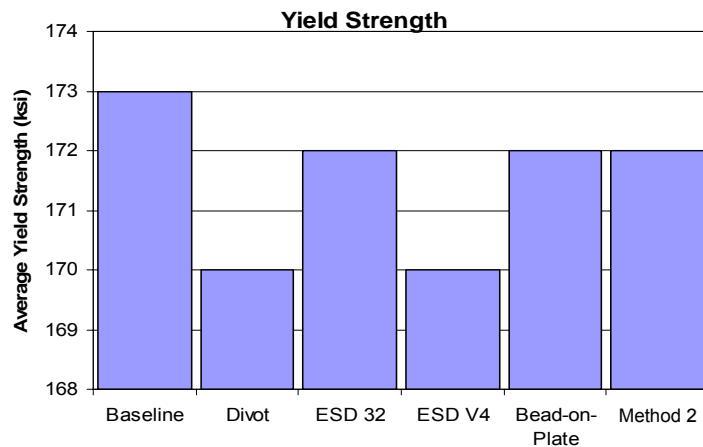
January 25, 2007

Advanced Surfaces And Processes, Inc.

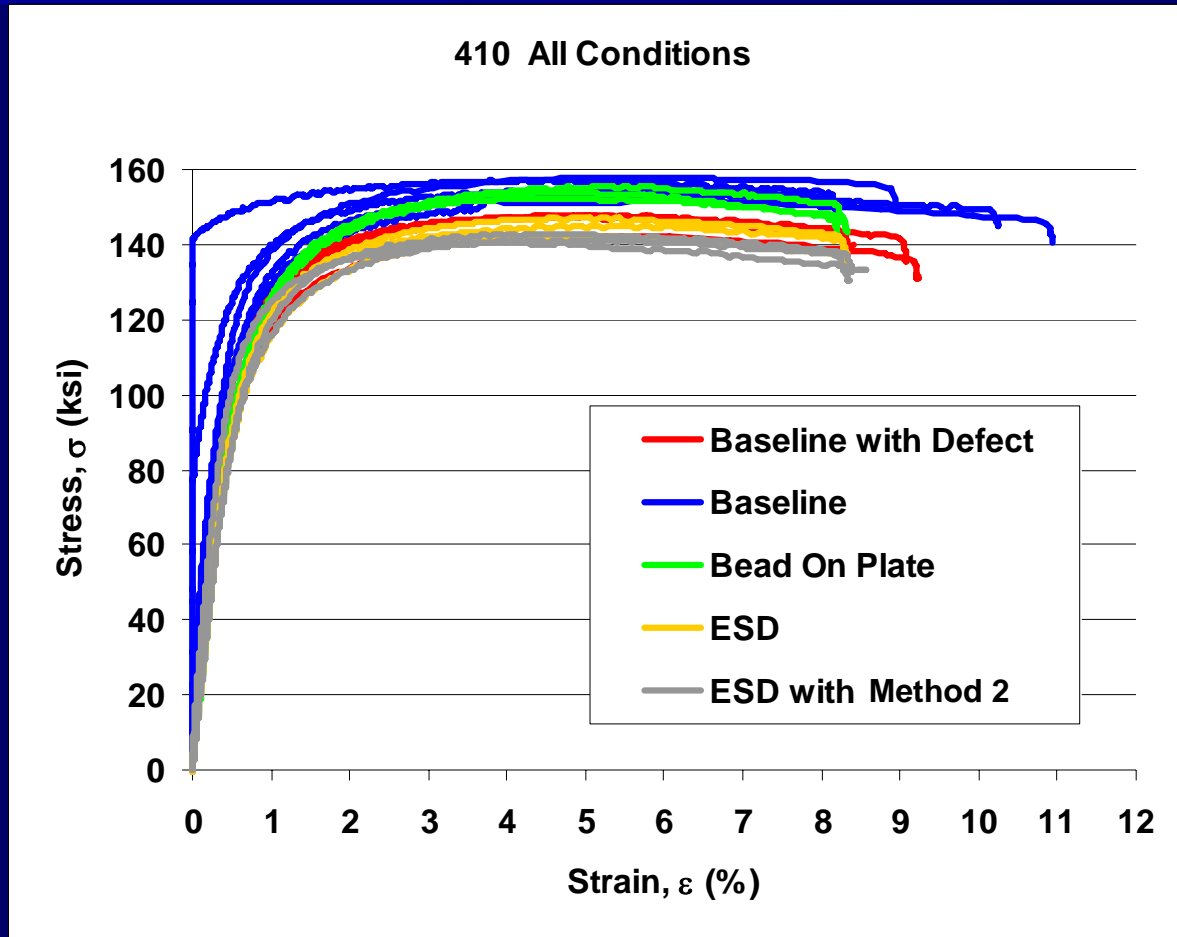
20

410 Stainless Steel

Tensile



410 Stainless Steel Tensile



410 Stainless Steel Corrosion

ASTM B117

**CASCADE™
TEK**

Cascade Technical Sciences, Inc.

TEST EQUIPMENT LIST

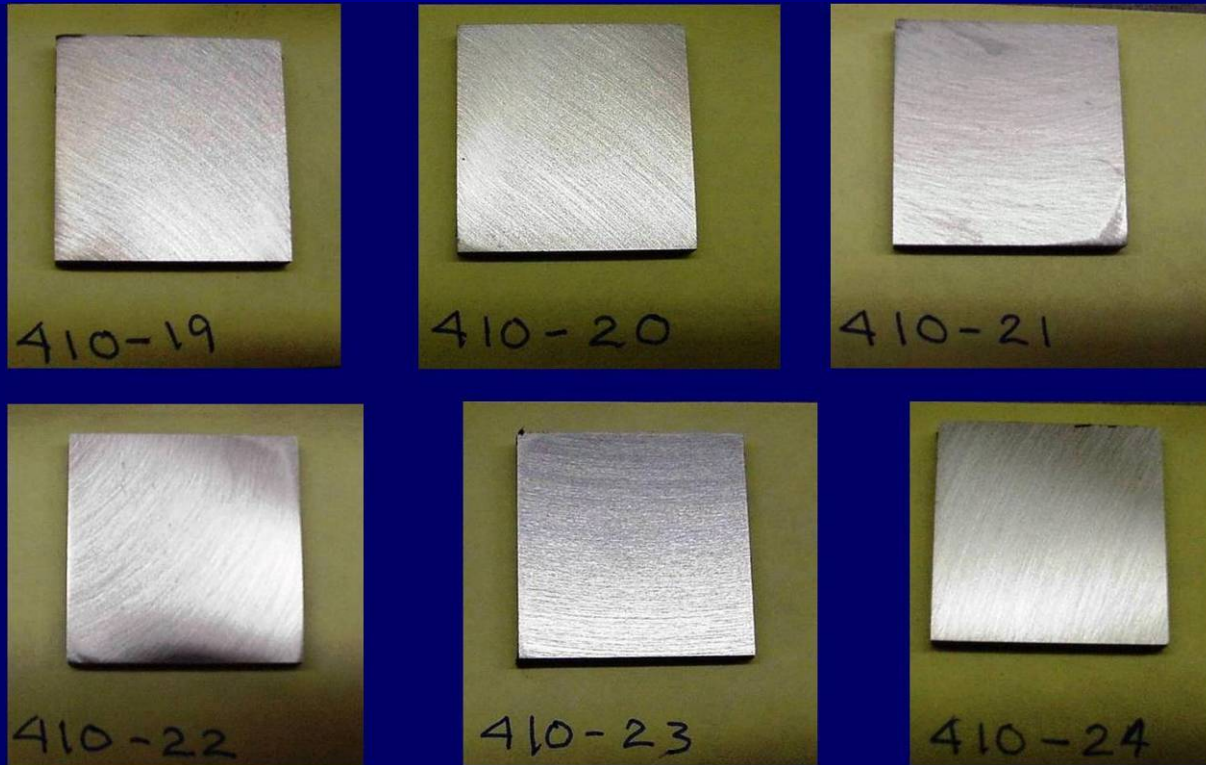
TEST: *SALT FOG* JOB NUMBER: *6100* DATE: *4-19-06*

EQUIPMENT DESCRIPTION	MANUFACTURER	MODEL	QUANTITY	UNIT	DATE RECEIVED (MM/DD/YY)	CALIBRATION DUE DATE (MM/DD/YY)
SALT FOG CHAMBER	SINGLETON	SCCH23SL	1	***	REFERENCE	***
CHART RECORDER	***	55000	1	***	***	***
HYDROMETER	FISHERBRAND	11-542A	1	***	FACTORY SET	***
TEST KIT ph	LAMOTTE	PP-BTS	1	***	***	***

Performed by
Cascade Technical Sciences, Inc.
Hillsboro, Oregon

410 Stainless Steel

Corrosion



Before Test

410 Stainless Steel Corrosion



After Test

Ti-6Al-4V

Ti-6Al-4V



Ti-6Al-4V Specimens Prepared in a Glove Box

January 25, 2007

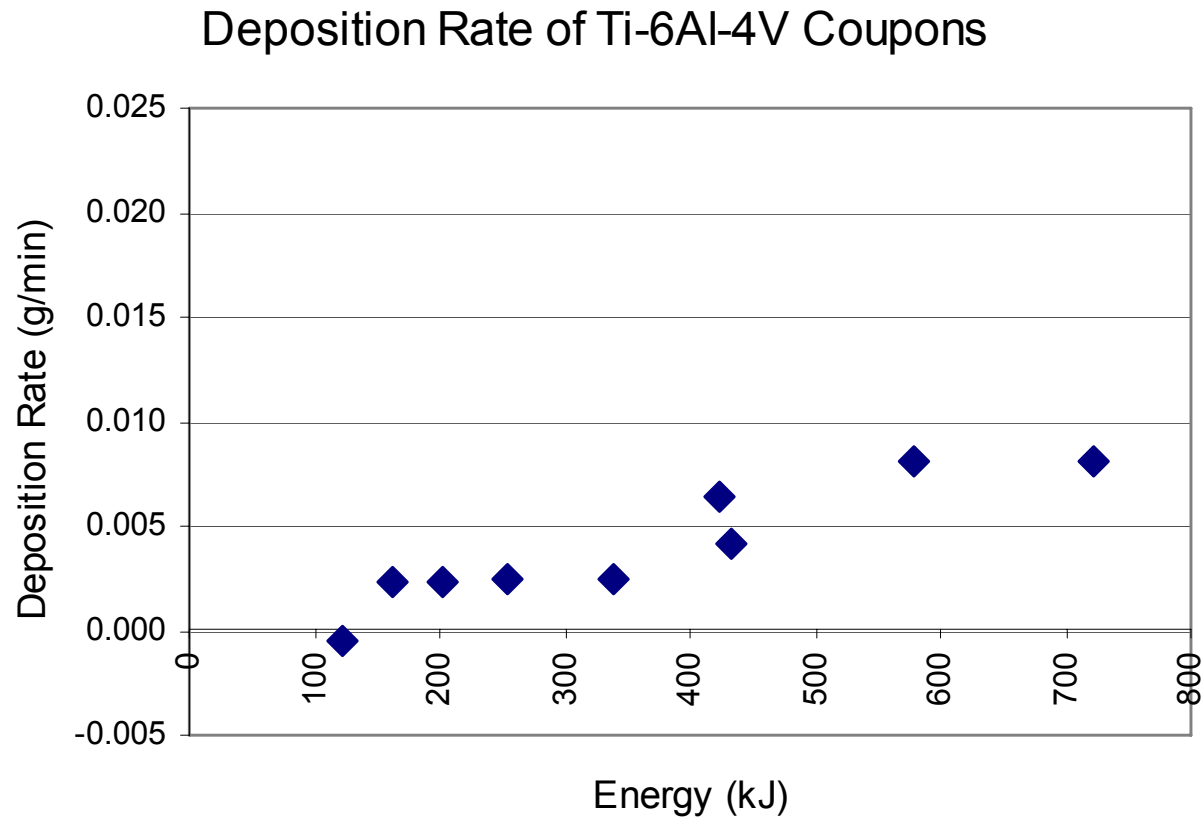
Advanced Surfaces And Processes, Inc.

Ti-6Al-4V

Optimization

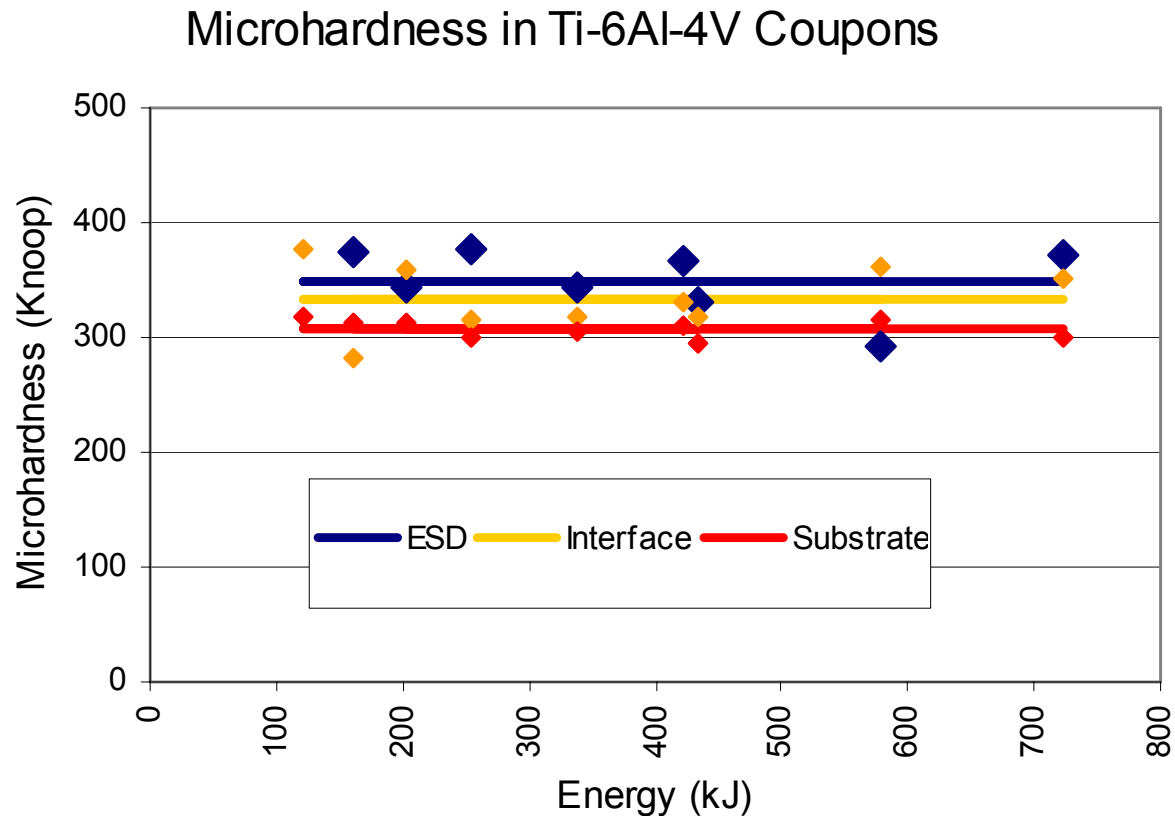
Run Order	Coupon Number	Pulse Rate (Hz)	Voltage (V)	Capacitance (mF)	Electrode Speed (rpm)
1	Ti-21	500	130	50	800
2	Ti-19	300	130	40	1200
3	Ti-11	300	170	50	1400
4	Ti-15	400	130	30	1400
5	Ti-13	400	170	40	800
6	Ti-20	400	90	50	1200
7	Ti-17	500	170	30	1200
8	Ti-14	500	90	40	1400
9	Ti-12	300	90	30	800

Ti-6Al-4V Optimization



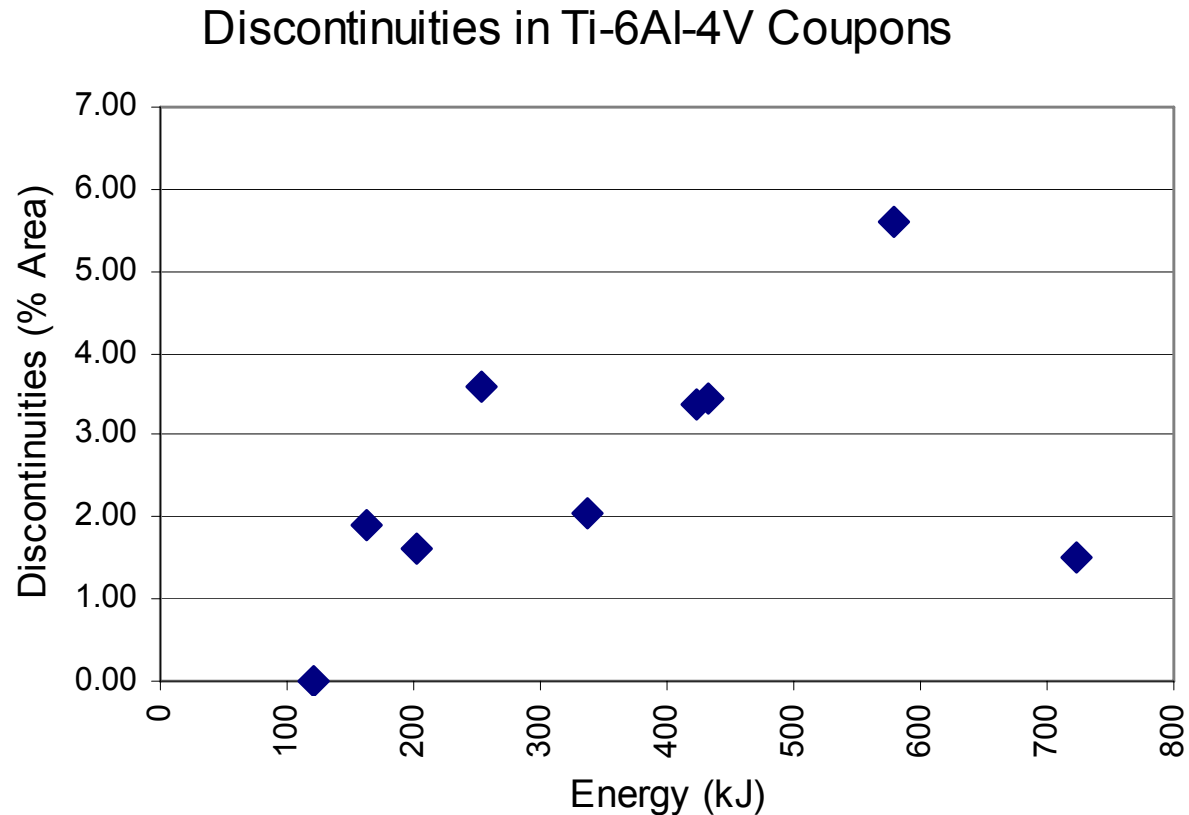
Ti-6Al-4V

Optimization



Ti-6Al-4V

Optimization



Ti-6Al-4V

Parameters Selected

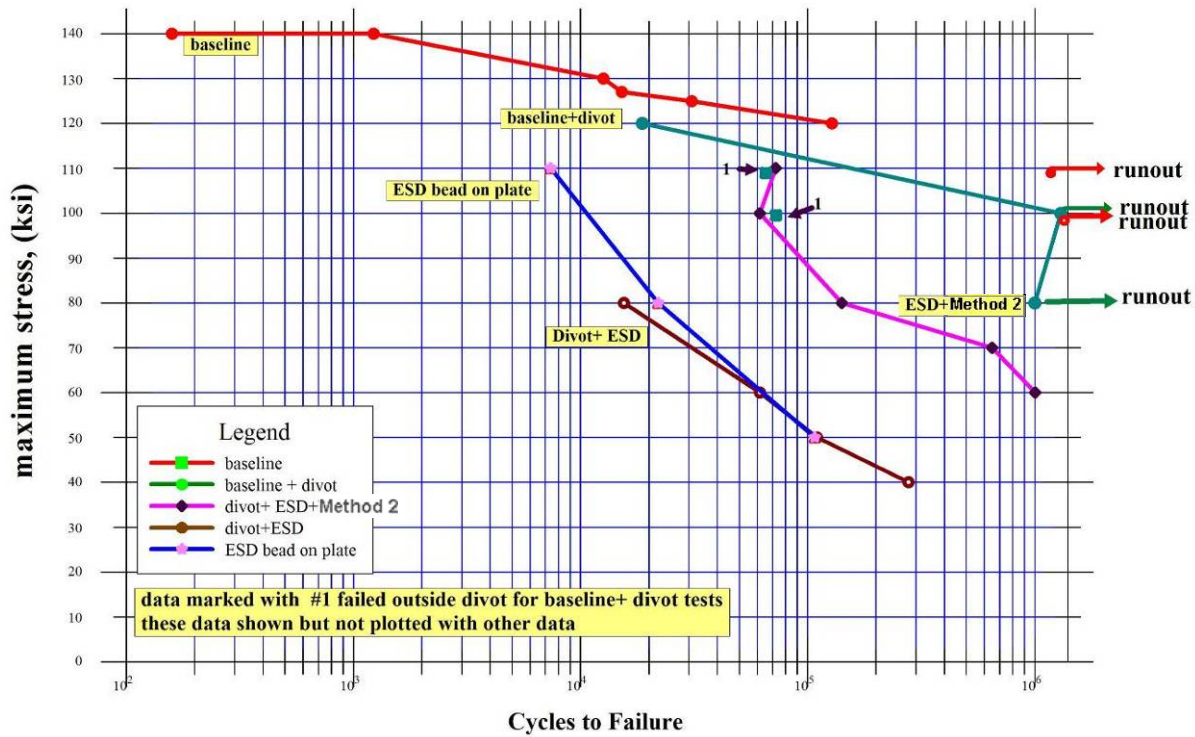
ESD Parameters – Based on DOE results:

- 500 Hz Pulse Rate
- 50 mF Capacitance
- 130 volts Voltage
- 1400 rpm electrode rotation speed

Ti-6Al-4V

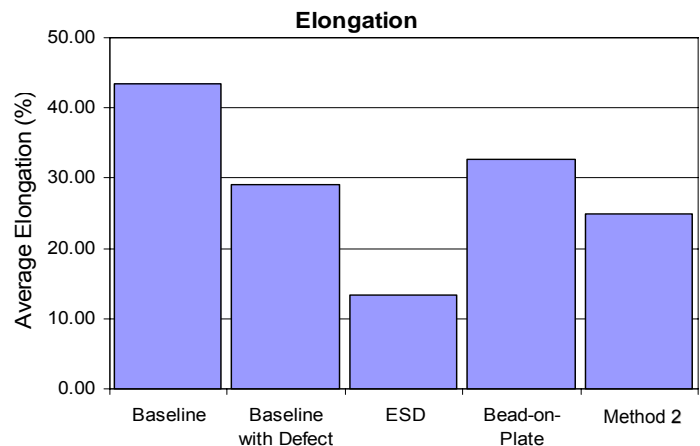
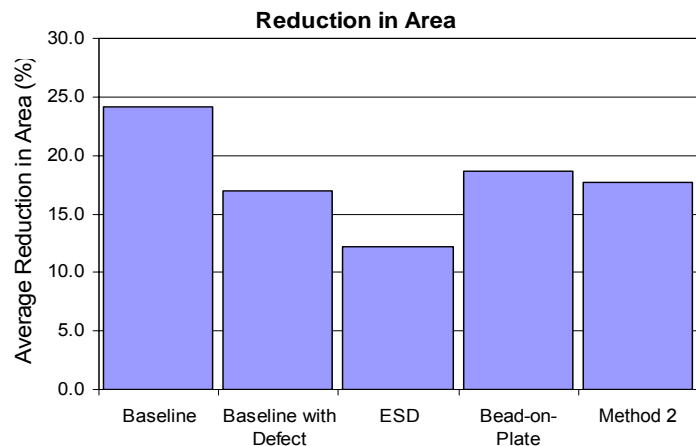
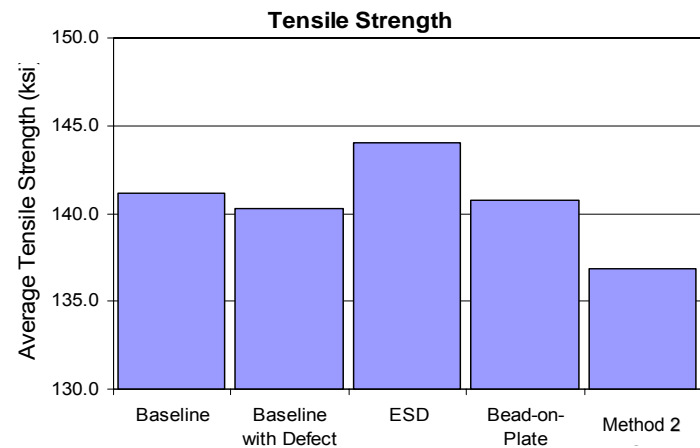
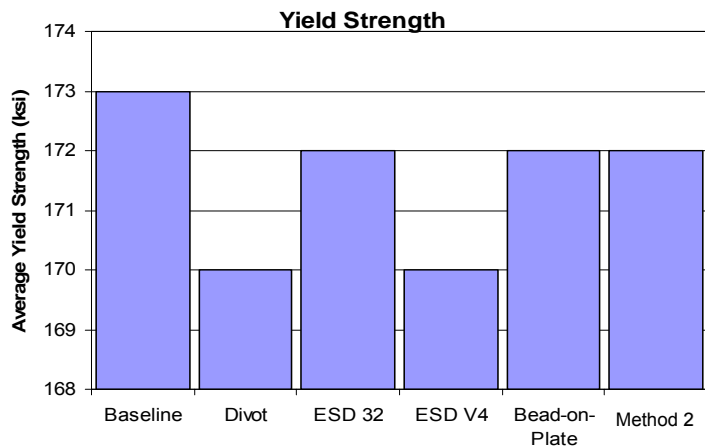
Fatigue

Titanium 6-4 Axial Fatigue Test Results (R=0.05)



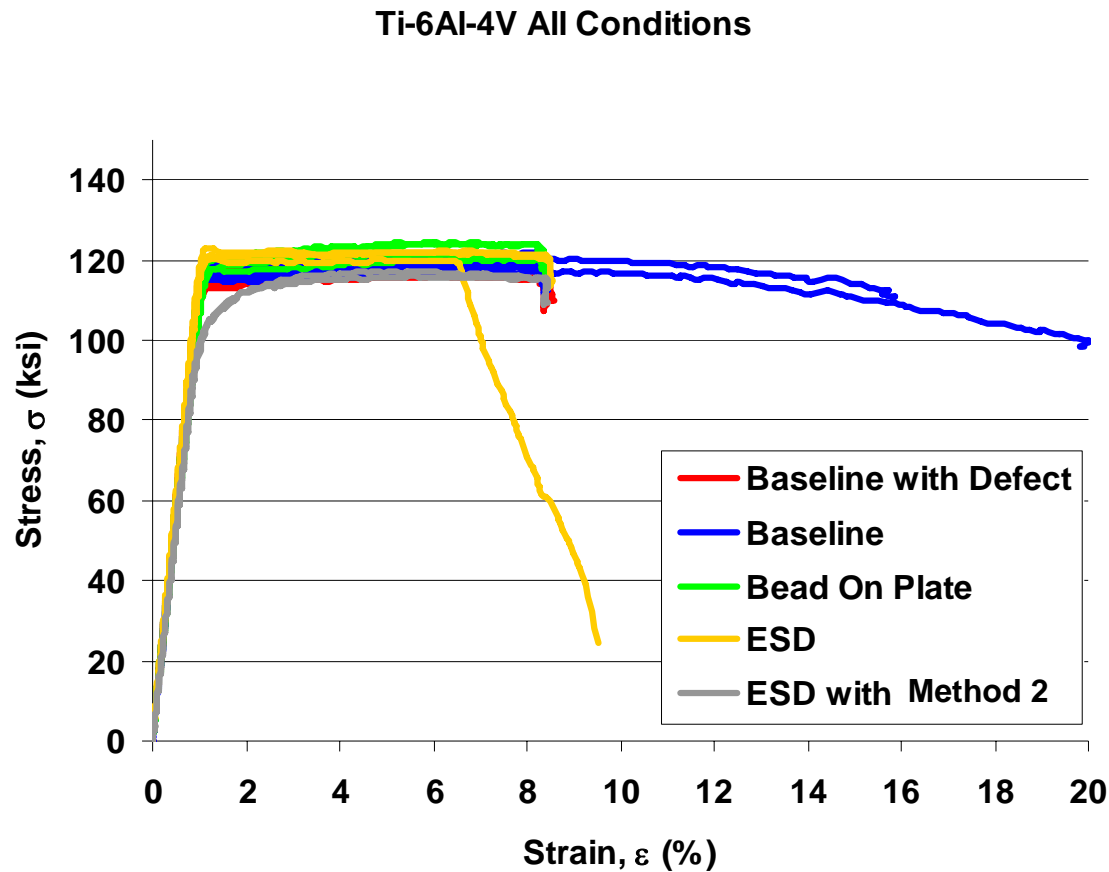
Ti-6Al-4V

Tensile



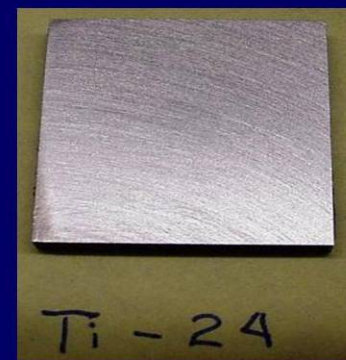
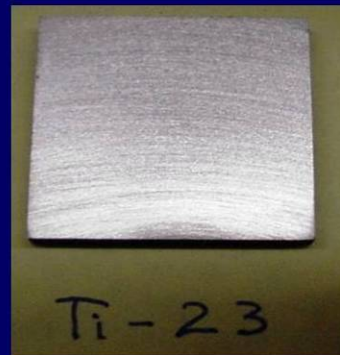
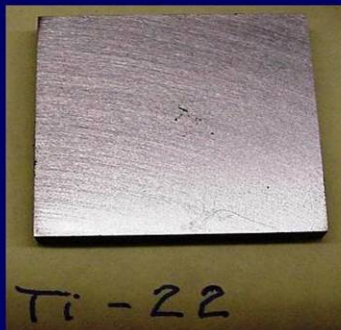
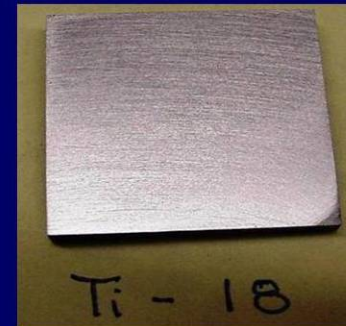
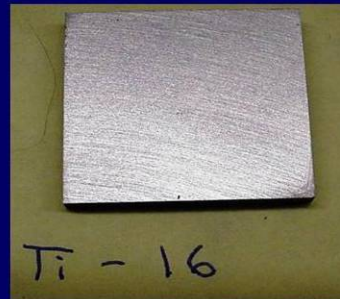
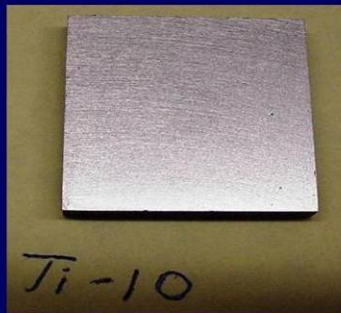
Ti-6Al-4V

Tensile



Ti-6Al-4V

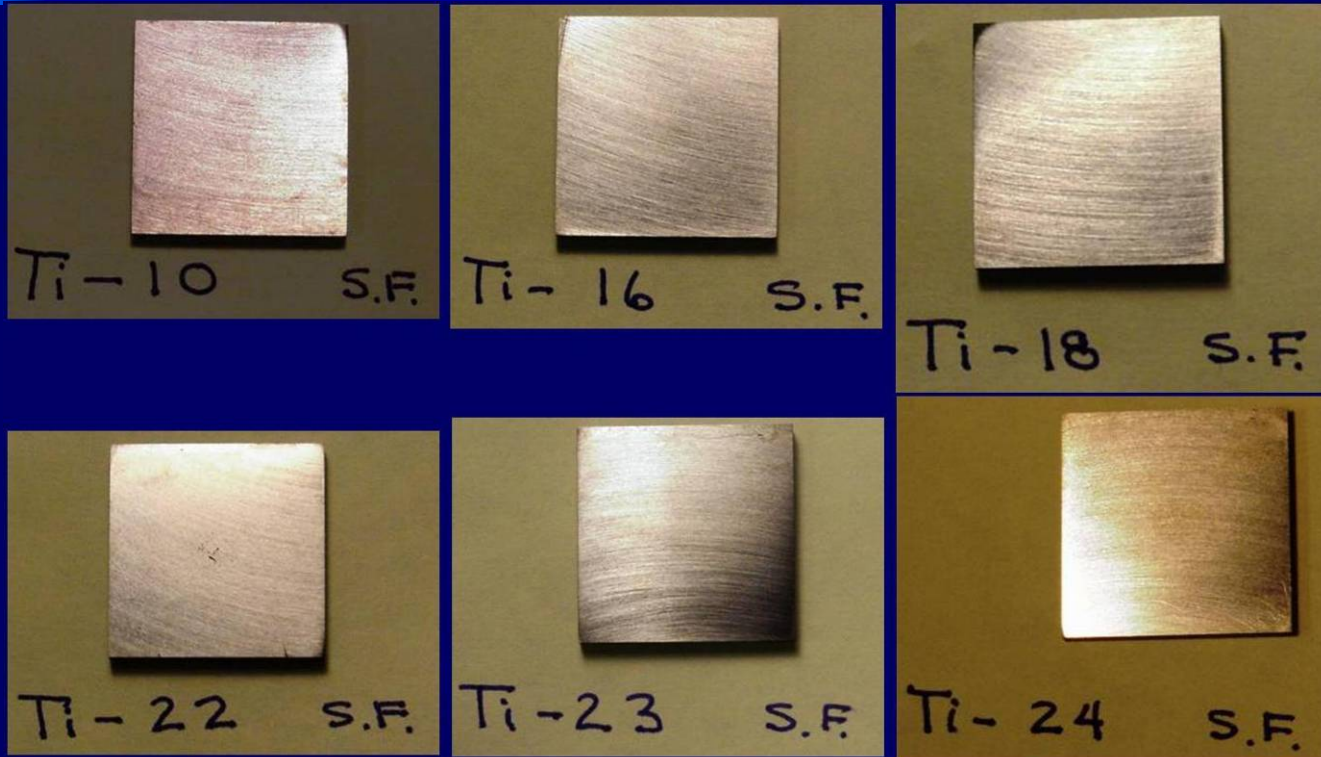
Corrosion



Before Test

Ti-6Al-4V

Corrosion



After Test

Chrome-Plated IN 718

Chrome-Plated IN 718

Optimization

Run Order	Coupon Number	Pulse Rate (Hz)	Voltage (V)	Capacitance (mF)	Electrode Speed (rpm)
1	Chrome-1	300	100	10	800
2	Chrome-2	300	125	20	1200
3	Chrome-3	300	150	30	1400
4	Chrome-4	400	100	20	1400
5	Chrome-5	400	125	30	800
6	Chrome-6	400	150	10	1200
7	Chrome-7	500	100	30	1200
8	Chrome-8	500	125	10	1400
9	Chrome-9	500	150	20	800

Chrome-Plated IN 718

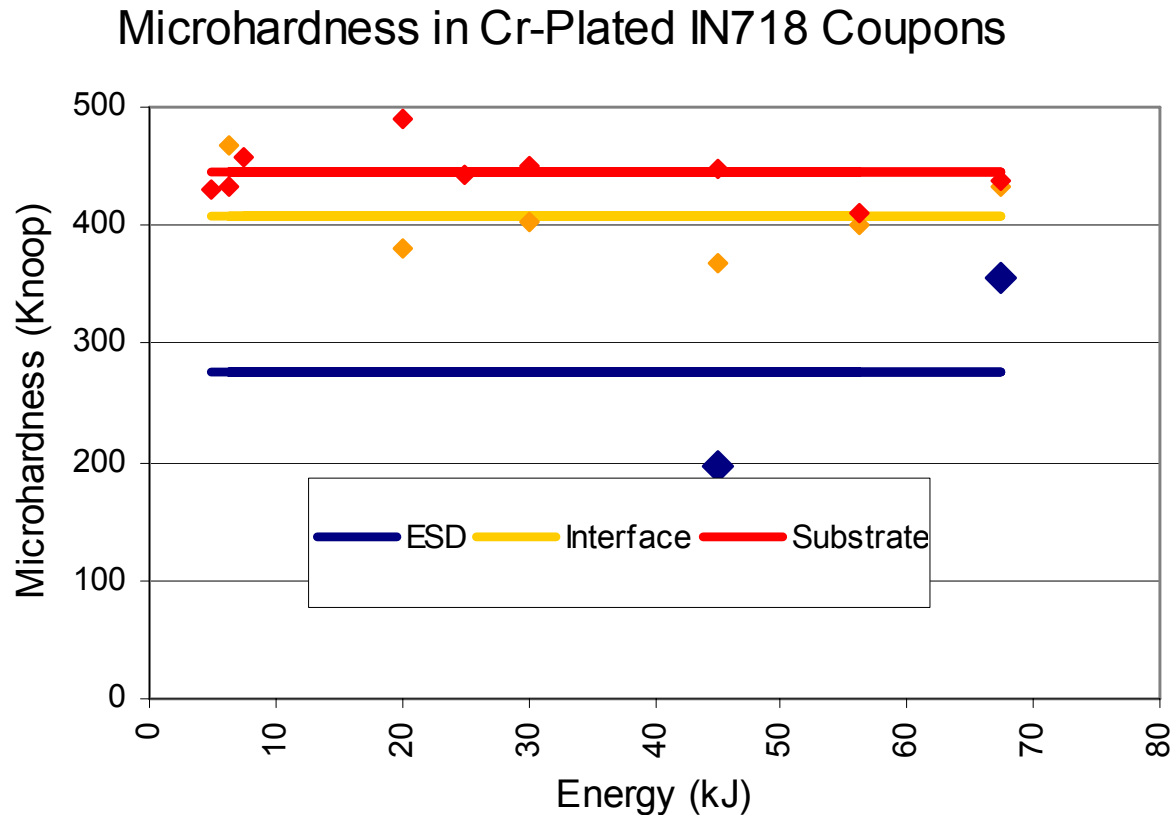
Optimization

Deposition Rate

Because of the difficulty with depositing material on chrome plated coupons, and with some areas of chrome plate debonding (or having been debonded), the weight gain measurements, and therefore, the deposition rates were not determined.

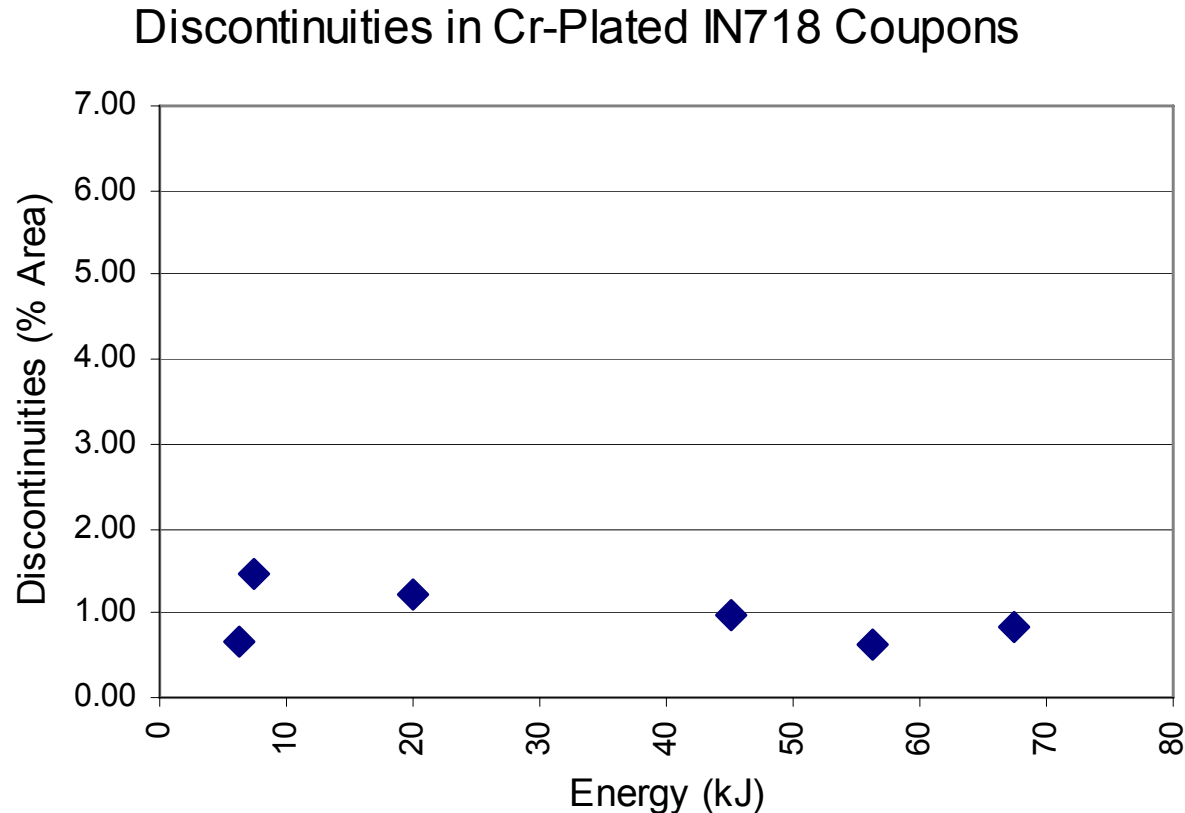
Chrome-Plated IN 718

Optimization



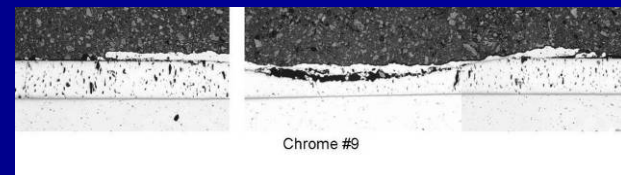
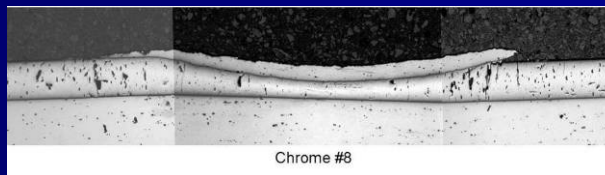
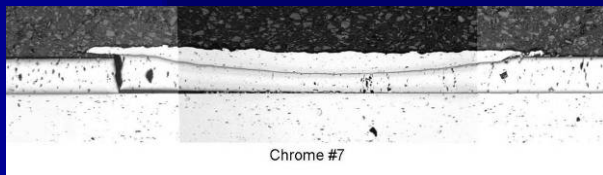
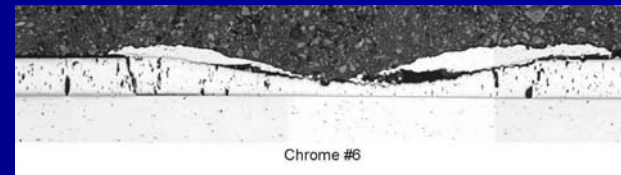
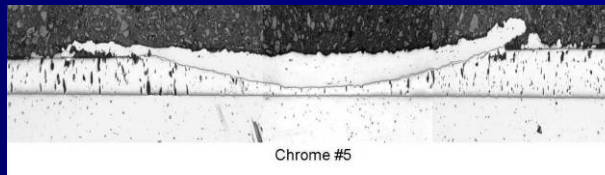
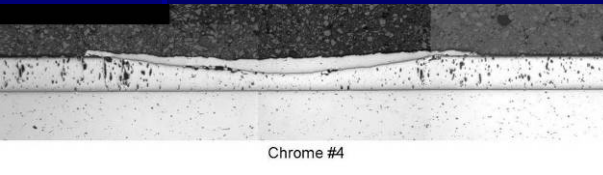
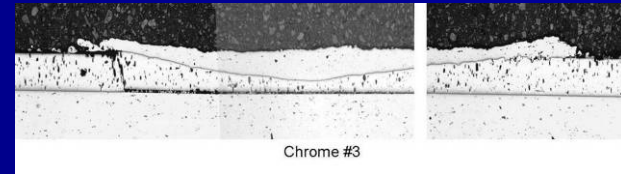
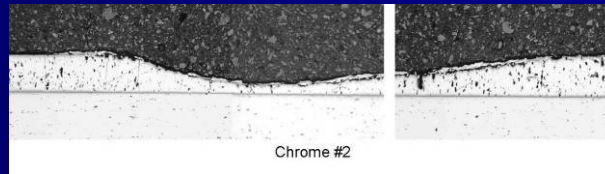
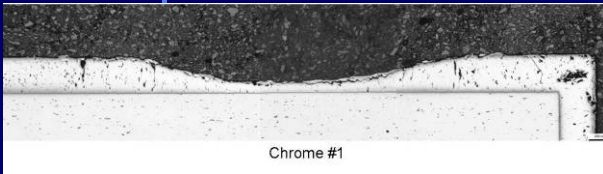
Chrome-Plated IN 718

Optimization



Chrome-Plated IN 718

Parameters Selected



Chrome-Plated IN 718

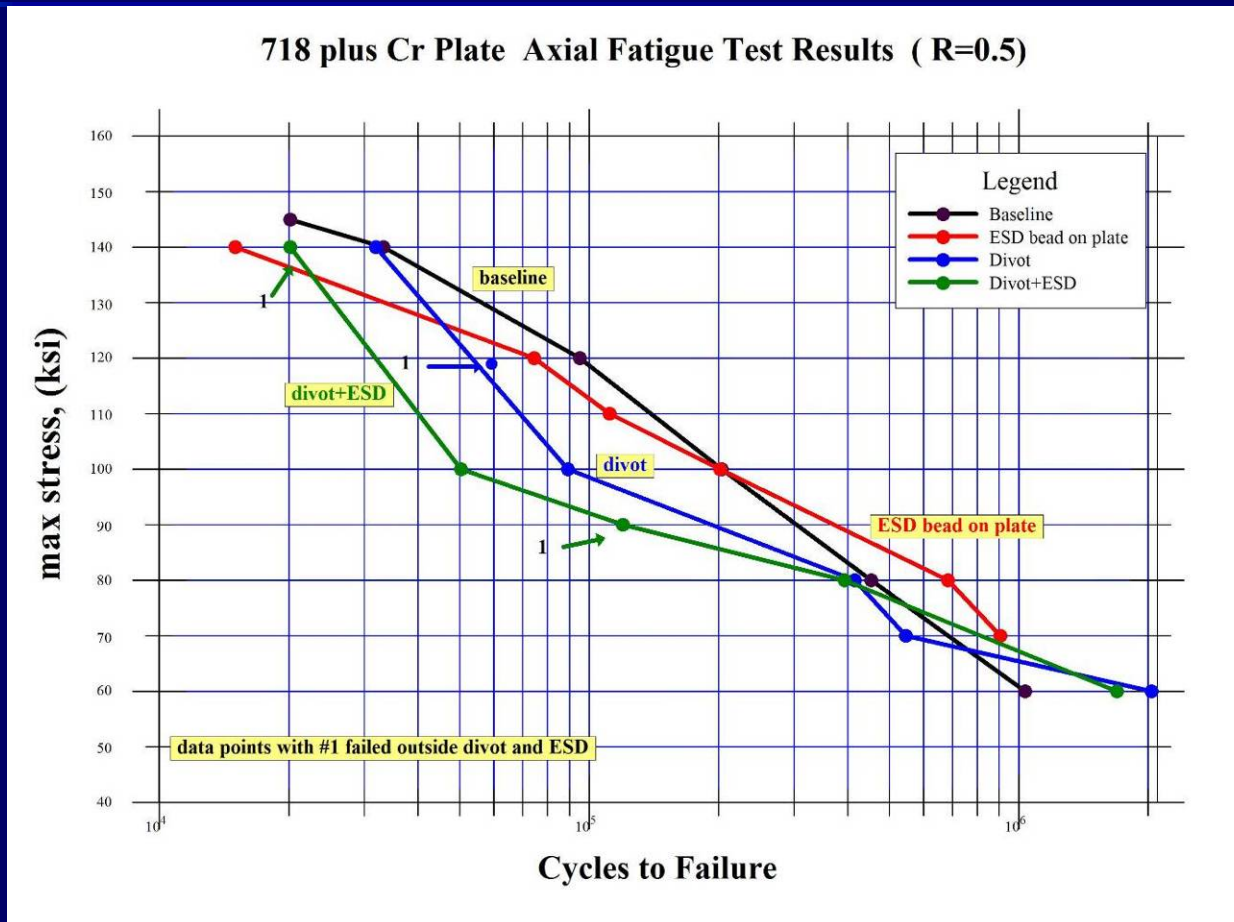
Parameters Selected

ESD Parameters – Based on Metallographic results:

- 300 Hz Pulse Rate
- 30 mF Capacitance
- 150 volts Voltage
- 1400 rpm electrode rotation speed

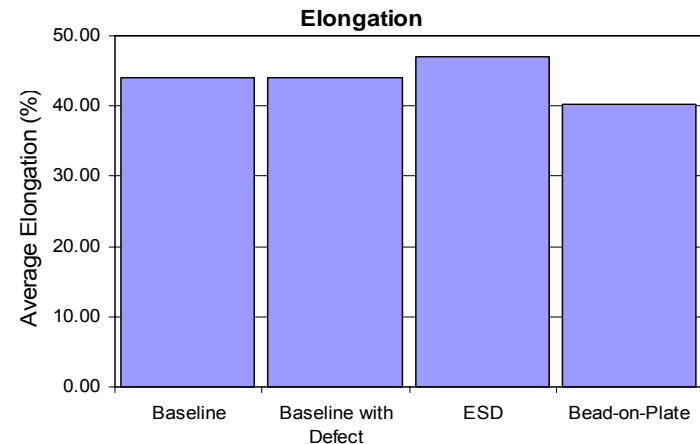
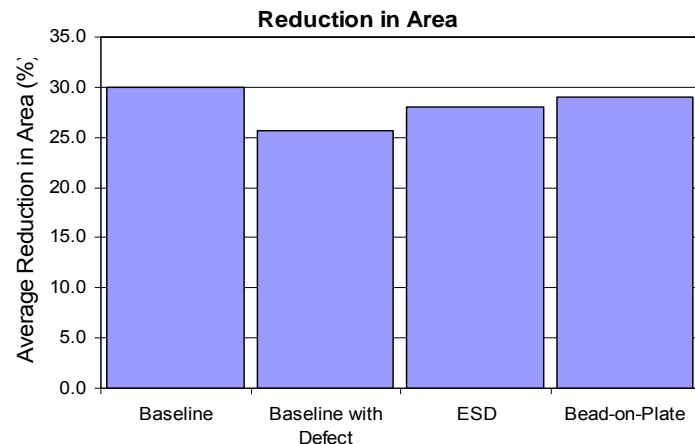
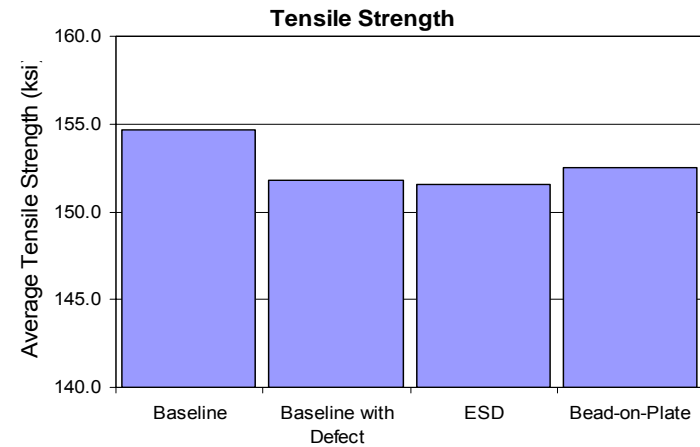
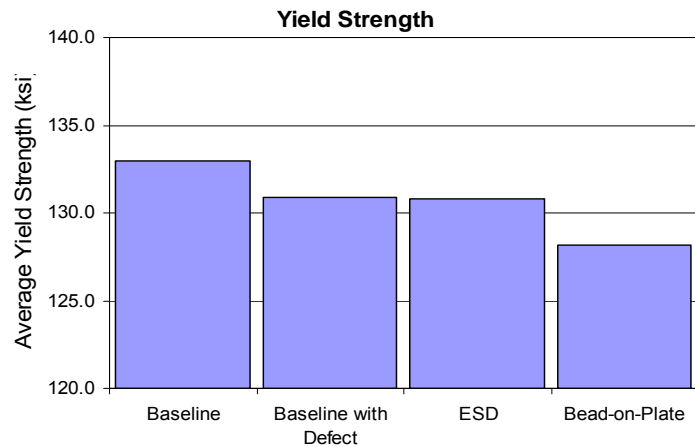
Chrome-Plated IN 718

Fatigue



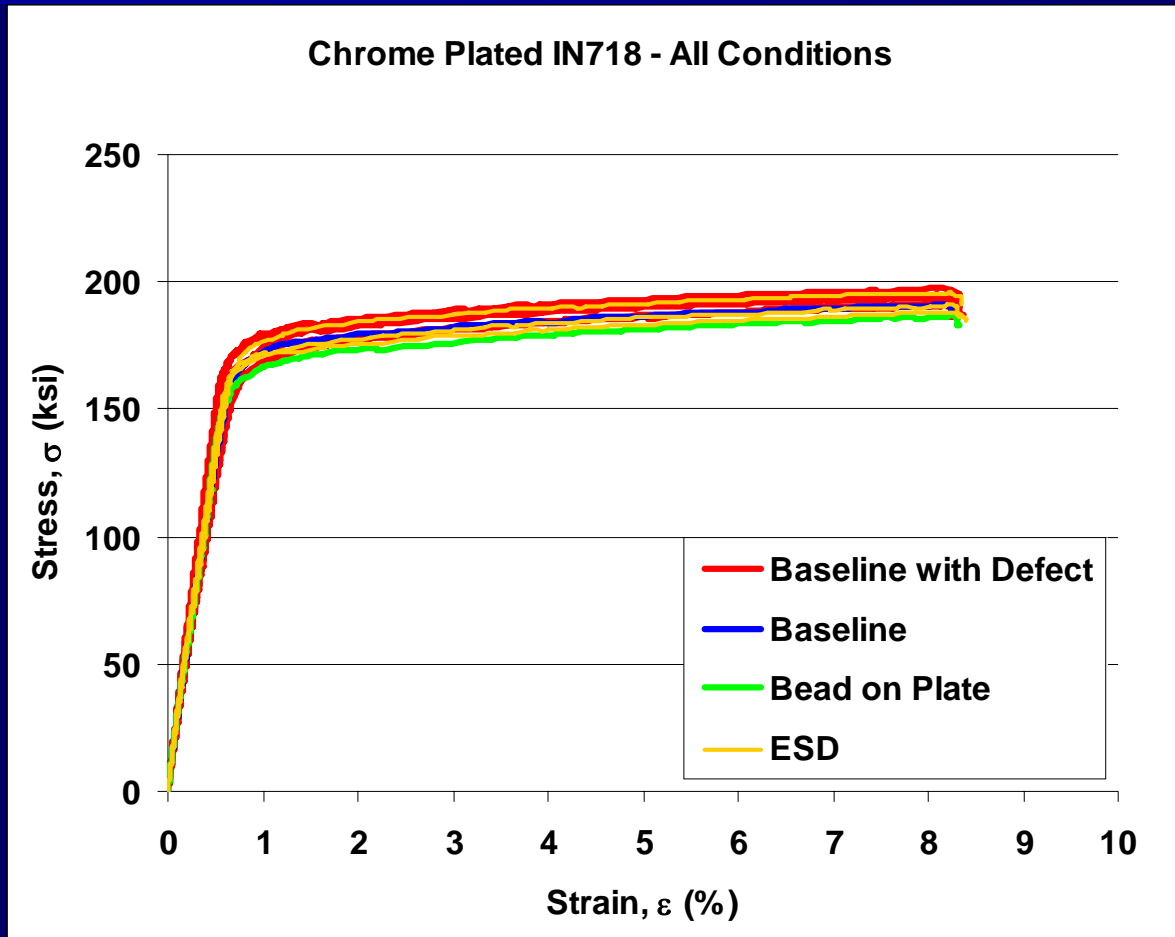
Chrome-Plated IN 718

Tensile



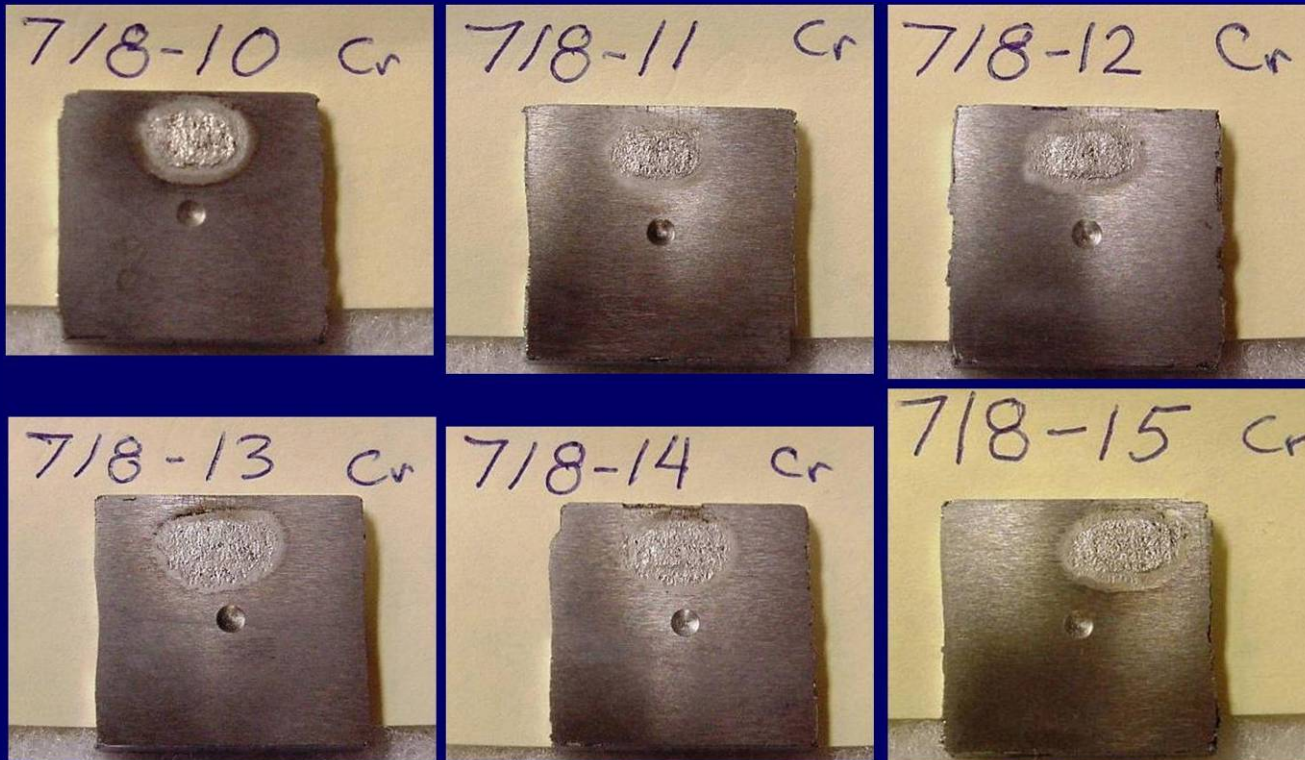
Chrome-Plated IN 718

Tensile



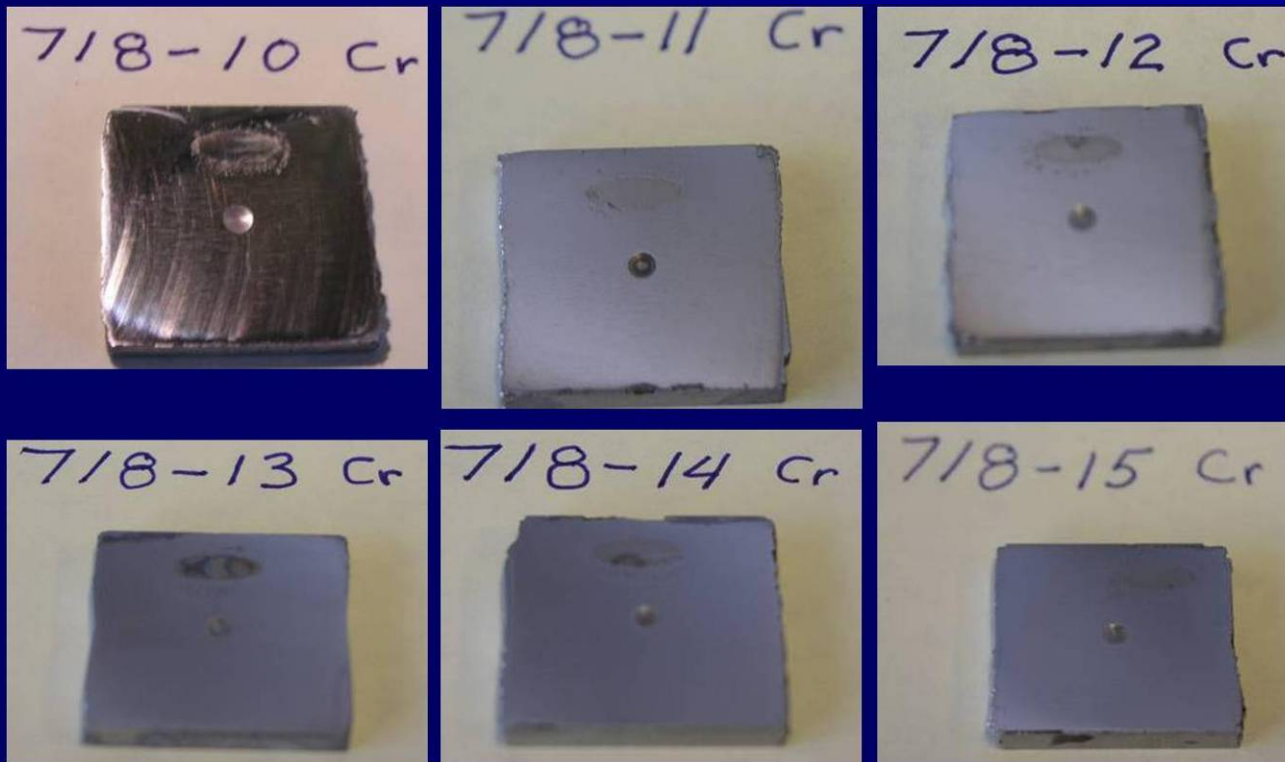
410 Stainless Steel

Corrosion



Before Test

410 Stainless Steel Corrosion



After Test

Project Complete

Addendum to Final Report sent to
ESTCP on December 12, 2006.

From Material Properties...

To Components

#5 Bearing Housing (410 SS)

Stator Segment (IN 718)

Compressor Rear Shaft (Chrome Plate)



Other Projects and Applications

- Army – Anniston – Abrams Tank
- Navy – Carderock – Nuclear Sub
- Army – Watervliet/Benet - Rail

ElectroSpark Deposition

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FAA Repair facility # V9PR575Y